

Final Report
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Evaluating the Information Content of Newly Retrieved SAGEII NO₂ Measurements in the Lower Stratosphere

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Original Research Objectives

1. Validate SAGE II NO₂ data using coincident measurements from ATMOS, HALOE, Lauder columns, LIMS, CLAES, ISAMS, ILAS, and balloons accounting for diurnal variations of NO₂ in the SAGE slant column, search for possible remaining aerosol interference in the NO₂ channel, and assess measurement errors, and temperature/pressure conversion errors in the SAGE retrieval.
2. Determine if secular changes exist in the stratospheric NO₂ density over the life of SAGE I/II.

Redirected Research Objectives

1. Calculate ozone trends in the stratosphere from Dobson Umkehr measurements.
2. Determine the vertical profile of trends at Arosa by using a sophisticated statistical model (MARCH) to separate solar, aerosol, and QBO effects on Dobson Umkehr measurements.
3. Compare Umkehr trends with SBUV and SAGE I/II trends in the stratosphere.

Summary of Results

Due to delays in the availability of the SAGE II v5.96 NO₂ data, this research was substantially redirected into studying Ozone trends in support of the SPARC/IOC/GAW Ozone Trends Assessment. Subsequent to that assessment, the SAGE II data, including both ozone and NO₂ retrievals were revised to version 6.0 a few months after the end of this grant. Nevertheless, we report here results not only from the ozone trend assessment

(summarized from publications) but also from the version 6.0 NO₂ evaluations (unpublished data).

Ozone trends

Dobson Umkehr measurements between 1979 and 1998 were used to assess potential drifts in SAGE and SBUV observations and to estimate annual ozone trends at midlatitudes. Comparisons of Umkehr time series to SAGE I/II time series constrains the potential drift in SAGE I/II ozone to approximately 0.2 ± 0.2 %/year [Harris *et al.*, 1998]. The combined trends of Umkehr, SAGE I/II, and SBUV(/2) indicate continued significant ozone decline throughout the stratosphere with a maximum of -0.8 ± 0.2 (2σ) %/year at 40 km and a minimum trend of -0.1 ± 0.1 (2σ) %/year at 25 km [Cunnold *et al.*, 2000; Newchurch *et al.*, 2000; Randel *et al.*, 1999].

The trends at Arosa derived from a Multivariate AutoRegressive Combined Harmonics (MARCH) statistical model are within the range of 95% uncertainty range of the results from the Standard statistical model. The aerosol, solar, and QBO effects on Umkehr ozone at Arosa are separated by the MARCH model providing additional information on the solar and QBO influences on ozone at midlatitudes [Newchurch *et al.*, 2000b].

SAGE NO₂ assessment

We present comparison of SAGEII v5.931, v5.96, v6.0d and v6.0e with ATMOS v3.1 (e.g., Rinsland *et al.*, [1999]) as well as with HALOE v19 as part of our proposed SAGEII NO₂ measurement validation, isolating coincidence pairs as well as average zonal differences. Data and plots for the SAGEII NO₂ comparisons are available for anonymous ftp at: vortex.atmos.uah.edu under directory /outgoing/SAGE2

SAGEII-ATMOS Comparisons

Coincidence pairs result from using the following criteria: located within +/- 1500 km and within +/- 24 hrs. Few coincidence pairs occur for ATLAS-1, several for ATLAS-3, and none for ATLAS-2 or SpaceLab-3.

Zonal differences result from using the following criteria: located within +/- 2 weeks and +/- 5 latitude degrees from the desired SAGEII range. We have included ATMOS v3.1 latitude/altitude vmr contours as well as the corresponding SAGEII latitude/altitude vmr contours. Plots of latitude vs. date for the given zonal differences appear for both SAGEII and ATMOS, along with plots of zonally averaged ATMOS profiles overplotted onto a spaghetti plot of the coincident SAGEII profiles.

SAGEII-HALOE Comparisons

Zonal comparisons result from SAGEII-HALOE using the same criteria as for ATMOS comparisons within the same SAGEII latitude range. These comparisons include

latitude/altitude vmr contours for the group coincidences for SAGEII v5.931, v5.96, v6.0d, v6.0e, ATMOS v3.1, and HALOE v19. We also include SAGEII and HALOE NO₂ column between 22 and 38 averaged over the coincidence latitude range, as well as zonally averaged NO₂ concentration and vmr profiles and percent difference comparisons for these average profiles.

SAGEII v6.0E Sunset/Sunrise comparisons with ATMOS and HALOE

Our NO₂ comparisons for v6.0e sunset data corroborate Osterman and Salawitch's results for different times and places using MKIV observations. SAGEII v6.0e NO₂ sunset profiles are significantly higher than those measured by previous SAGEII versions, ATMOS, MkIV, and HALOE, with ATMOS exhibiting best agreement.

Between 22-38 km, the differences between SAGEII v6.0e, ATMOS, HALOE, and previous SAGEII versions range between 10-25% for April 1985, which corresponds to absolute differences of 0.75-1.75 ppbv, and between 15-50% for March 1992, April 1993, and November 1994, which correspond to absolute differences of 1.5-4 ppbv. These differences are consistent with Randall's POAM comparison results. Similar differences occur in NO₂ column calculations. The very large standard deviation of NO₂ column calculations for March 1992, are attributed to strong sulfate aerosol loading below 25 km from the Mt. Pinatubo eruption. The standard deviations for the SAGEII v6.0d and v6.0e are considerably smaller than earlier SAGEII versions, due to the availability of fewer profiles for the v6 columns.

In general, ATMOS v3.1 sunset measurements tend to lie in between those for SAGEII v6.0e and other measurements considered (SAGEII v5.931, v5.96 and HALOE v19). Therefore the SAGE-ATMOS differences are smaller than the SAGE-HALOE or SAGE-MkIV differences.

As expected we observe relatively lower increases in NO₂ abundance for sunrise with respect to sunset measurements. Differences between SAGEII v6.0e and v5.931, v5.96, and HALOE v19 are on the order of 10-40% between 22-38 km for November 1994, which corresponds to an absolute difference between 1.5-2.5 ppbv. Differences in the range of -30 to 30% are observed for April 1985, March 1992, and April 1993, which correspond to absolute differences of -0.5 to 0.5 ppbv.

In general SAGE/other differences are smallest near the vmr peak around 35 km, and increase both above and below that altitude. The average sunrise differences are smaller than the average sunset differences.

Osterman and Salawitch note that a decrease of approximately 1.5 ppbv in zonally averaged NO₂ volume mixing ratio profiles (as would result from a potential change in the retrieval algorithm) will result in better measurement agreement between SAGEII v6.0e, and HALOE v19. Upon simulating this proposed correction to our zonally averaged NO₂ vmr profiles, we see an improvement in measurement agreement for sunset

data, but a worsened agreement in sunrise data, with the exception of mid-stratospheric measurements for November 1994.

Diurnally Corrected ATMOS NO₂ Data

Diurnally corrected ATMOS NO₂ average profiles differ very little from the uncorrected profiles, between 22-38 km, as expected from [Newchurch *et al.*, 1996]. At their maximum difference, the diurnally corrected (DC) profiles are about 5% lower than the uncorrected. Differences of 10-28% at 15-20 km and 40-45 km appear where the DC profiles are lower than the non-DC profiles, with the exception of the lower 10 km of the March 1992 profile.

Publications

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